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Donna Gillespie; Timothy Veal; L. Douglas Bell; James Schuck

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14. ABSTRACT
The 2013 Fall Meeting of the Materials Research Society was held December 1-6 in Boston, Massachusetts. The world's foremost international scientific gathering for materials research, the MRS meeting showcases leading interdisciplinary research in both fundamental and applied areas, coordinated by over 200 scientists from both academia and industry in 19 countries around the world. Symposia concerning the utilization of a broad range of advanced materials in electronics and photonics devices and applications were available, from oxide semiconductors to diamond, compound semiconductors and magnetic nanostructures. Recent advances in

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Report Title

2013 Materials Research Society Fall Meeting - Final Technical Report

ABSTRACT

The 2013 Fall Meeting of the Materials Research Society was held December 1-6 in Boston, Massachusetts. The world's foremost international scientific gathering for materials research, the MRS meeting showcases leading interdisciplinary research in both fundamental and applied areas, coordinated by over 200 scientists from both academia and industry in 19 countries around the world. Symposia concerning the utilization of a broad range of advanced materials in electronics and photonics devices and applications were available, from oxide semiconductors to diamond, compound semiconductors and magnetic nanostructures. Recent advances in plasmonics, metamaterials and photoactive organic materials, as well as organic microlasers, comprised separate themes. Two topical symposia concerning large-area patterning and solution-based processing of functional electronic/photonic materials and devices were included. Symposia concerning the synthesis and function of a broad range of nanomaterials were available, from semiconductor nanowires to nanocomposites, carbon nanostructures and cellular materials. Recent advances in microelectromechanical systems, phonon engineering, nanoscale patterning and self-assembly, and other emerging nanomaterials comprise separate themes. Finally, two topical symposia concerning nanostructured materials in extreme environments and elastic strain engineering for unprecedented material properties were included.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper
06/18/2014 36.00	Yoshitaka Nakano, Liwen Sang, Masatomo Sumiya. Electrical Characterization of Thick InGaN Films for Photovoltaic Applications, MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.205
06/18/2014 37.00	Kanika Bansal, Shouvik Datta. Dielectric Response of Light Emitting Semiconductor Junction Diodes: Frequency and Temperature Domain Study, MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.206
06/18/2014 38.00	Shailesh Kumar Madisetti, Vadim Tokranov, Andrew Greene, Steven Novak, Michael Yakimov, Serge Oktyabrsky, Steven Bentley, Ajey P. Jacob. GaSb on Si: Structural Defects and Their Effect on Surface Morphology and Electrical Properties, MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.219
06/18/2014 25.00	T.B. Hoffman, Y. Zhang, J.H. Edgar, D.K. Gaskill. Growth of hBN Using Metallic Boron: Isotopically Enriched h10BN and h11BN, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.48
06/18/2014 26.00	Mei Shen, Amir Afshar, Manisha Gupta, Gem Shoute, Ken Cadien, Ying Yin Tsui, Doug Barlage. Electrical Characteristics of TiW/ZnO Schottky contact with ALD and PLD, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.49
06/18/2014 27.00	Shinya Okamoto, Satoshi Ichikawa, Yosuke Minowa, Masaaki Ashida. Optical Fabrication of Semiconductor Single-Crystalline Microspheres in Superfluid Helium, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.100
06/18/2014 28.00	Tobias Jochum, Daniel Ness, Marieke Dieckmann, Katja Werner, Jan Niehaus, Horst Weller. Production and biofunctionalization of elongated semiconducting nanocrystals for ex-vivo applications, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.101
06/18/2014 29.00	Yongkun Sin, Stephen LaLumondiere, William Lotshaw, Steven C. Moss. Carrier Dynamics in Self-Assembled InAs QD Laser Structures and Broad-Area InAs QD Lasers Grown by Molecular Beam Epitaxy, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.103
06/18/2014 30.00	Kenji Kikuchi, Shigeyuki Imura, Kazunori Miyakawa, Hiroshi Ohtake, Misao Kubota, Eiji Ohta. Improved Electrical Properties of Ga2O3:Sn/CIGS Hetero-Junction Photoconductor, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.104
06/18/2014 31.00	Tetsuro Hemmi, Koji Nakayama, Katsunori Asano, Tetsuya Miyazawa, Hidekazu Tsuchida. Cause of Forward Voltage Degradation for 4H-SiC PiN Diode with Additional Process, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.105
06/18/2014 32.00	Nichole M. Hoven, Glen Hillier, Seth M. Hubbard, David V. Forbes, Brittany L. Smith. OMVPE of InAlAs Using Alternative Al and As Precursors, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.106
06/18/2014 3.00	H. von Wenckstern, Z. Zhang, J. Lenzner, F. Schmidt, M. Grundmann. A continuous composition spread approach towards monolithic, wavelength-selective multichannel UV-photo-detector arrays, MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.19

06/18/2014 4.00 Christian T. Reindl, Peter J. Klar, Thomas Sander. Breaking of Raman selection rules in Cu2O by intrinsic point defects,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.47

06/18/2014 2.00 Eichi Nagatomi, Naoya Yamaguchi, Takahiro Kato, Koichiro Ohishi, Yasuhiro Tamayama, Kanji Yasui. Effects of N2O addition on the properties of ZnO thin films grown using high-temperature H2O generated by catalytic reaction,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.20

06/18/2014 5.00 Tegshjargal Khishigjargal, Kazuyoshi Ueda. Density Functional Study of Benzoic Acid Derivatives Modified SnO2 (110) Surface,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.46

06/18/2014 6.00 T. Hanawa, N. Kikuchi, K. Nishio, K. Tonooka, R. Wang, T. Mamiya. Epitaxial Growth of (Na,K)NbO3 based materials on SrTiO3 by pulsed laser deposition,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.84

06/18/2014 7.00 Toshihiro Nakamura, Masaki Yamada, Osamu Sakai. Correlation of resistance switching behaviors with dielectric functions of manganite films: A study by spectroscopic ellipsometry,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.85

06/18/2014 8.00 K.P. Hering, A. Polity, B. Kramm, A. Portz, B.K. Meyer. Synthesis and Characterization of Copper Oxide Compounds,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.86

06/18/2014 9.00 P. Schlupp, H. von Wenckstern, M. Grundmann. Amorphous zinc-tin oxide thin films fabricated by pulsed laser deposition at room temperature,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.117

06/18/2014 10.00 D. S. L. Pontes, F. M Pontes, Marcelo A. Pereira-da-Silva, O. M. Berengue, A. J. Chiquito, E. Longo. Structural and electrical properties of LaNiO3 thin films grown on (100) and (001) oriented SrLaAlO4 substrates by chemical solution deposition method,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.116

06/18/2014 11.00 Juan Paolo Bermundo, Yasuaki Ishikawa, Haruka Yamazaki, Toshiaki Nonaka, Yukiharu Uraoka. Highly reliable passivation layer for a-InGaZnO thin-film transistors fabricated using polysilsesquioxane,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.118

06/18/2014 12.00 M. Martyniuk, D. Baldwin, R. Jeffery, K.K.M.B.D. Silva, R.C. Woodward, J. Cliff, R.N. Krishnan, J.M. Dell, L Faraone. Characterization of mechanical, optical and structural properties of bismuth oxide thin films as a write-once medium for blue laser recording,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.145

06/18/2014 13.00 Ze Jia, Jianlong Xu, Xiao Wu, Mingming Zhang, Naiwen Zhang, Jizhi Liu, Zhiwei Liu, Juin J. Liou. Metal-Semiconductor-Insulator-Metal Structure Field-Effect Transistors Based on Zinc Oxides and Doped Ferroelectric Thin Films,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.130

06/18/2014 14.00 Yogesh Sharma, Pankaj Misra, Ram S. Katiyar. Structural and Electrical Characteristics of Ternary Oxide SmGdO3 for Logic and Memory Devices,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.129

06/18/2014 17.00 Forough Mahmoudabadi, Ta-Ko Chuang, Jerry Ho Kung, Miltiadis K. Hatalis. High Performance IGZO TFTs with Modified Etch Stop Structure on Glass Substrates,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.192

06/18/2014 15.00 Altynbek Murat, Julia E. Medvedeva. Native point defects in multicomponent transparent conducting oxides,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.144

06/18/2014 18.00 Bing Chen, Dong Liu, Bin Gao, Yiran Wang, Lifeng Liu, Xiaoyan Liu, Jinfeng Kang. Solution Processed Resistive Random Access Memory Devices for Transparent Solid-State Circuit Systems,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.252

06/18/2014 19.00 Peter Schlupp, Stefan Müller, Christof Peter Dietrich, Holger von Wenckstern, Marius Grundmann, Robert Heinhold, Florian Schmidt, Hyung-Suk Kim, Martin Ward Allen. A DLTS study of a ZnO microwire, a thin film and bulk material,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.253

06/18/2014 20.00 Nagendra Pratap Singh, S.A. Shivashankar, Rudra Pratap. Defect Driven Emission from ZnO Nano Rods Synthesized by Fast Microwave Irradiation Method for Optoelectronic Applications,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.254

06/18/2014 21.00 Alexander J. E. Rettie, Luke G. Marshall, Jianshi Zhou, C. Buddie Mullins, Jeffery Lindemuth. Electronic Transport Characterization of BiVO4 Using AC Field Hall Technique,
MRS Proceedings, (03 2014): 0. doi: 10.1557/opl.2014.270

06/18/2014 22.00 G. Medina, P.A. Stampe, R.J. Kennedy, R.J. Reeves, G.T. Dang, A. Hyland, M.W. Allen, M.J. Wahila, L.F. J. Piper, S. M. Durbin. Characterization of Tin Oxide Grown by Molecular Beam Epitaxy,
MRS Proceedings, (03 2014): 0. doi: 10.1557/opl.2014.305

06/18/2014 39.00 Andrzej Taube, Maciej Kozubal, Jakub Kaczmarski, Marcin Juchniewicz, Adam Barcz, Jan Dyczewski, Rafa? Jakie?a, El?bieta Dynowska, Micha? Adam Borysiewicz, Pawe? Prystawko, Jakub Jasi?ski, Pawe? Borowicz, Eliana Kami?ska, Anna Piotrowska. High resistivity isolation for AlGaN/GaN HEMT using Al double-implantation,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.220

06/18/2014 40.00 John Hennessy, L. Douglas Bell, Shouleh Nikzad, Puneet Suvarna, Jeffrey M. Leathersich, Jonathan Marini, F. (Shadi) Shahedipour-Sandvik. Atomic-layer Deposition for Improved Performance of III-N Avalanche Photodiodes,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.204

06/18/2014 41.00 Oleg Rabinovich. InGaN structure influence on efficiency droop,
MRS Proceedings, (03 2014): 0. doi: 10.1557/opl.2014.336

06/18/2014 42.00 Ayman Salman Alofi, Gyaneshwar P. Srivastava. Effect of Tensile Strain on Thermal Properties of Graphene,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.182

06/18/2014 43.00 Jawaher Al-Otaibi, Gyaneshwar P. Srivastava. A Theoretical study of the Thermoelectric Transport Coefficients of n-type PbTe,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.183

06/18/2014 44.00 Greg Sun, Jacob B. Khurgin, Din Ping Tsai. Feasibility of spoof surface plasmon waveguide enabled ultrathin room temperature THz GaN quantum cascade laser,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.184

06/18/2014 45.00 R. Al-Saigh, A. Shalini, G. P. Srivastava, R. J. Hicken, R. Calarco. Excitation and detection of coherent optical phonon modes in epitaxial cubic Ge 2 Sb 2 Te 5 thin films of different crystallographic orientation,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.185

06/18/2014 46.00 Kazushi Hayashi, Aya Hino, Hiroaki Tao, Yasuyuki Takanashi, Shinya Morita, Hiroshi Goto, Toshihiro Kugimiya. Evaluation of Sub-Gap States in Amorphous In-Ga-Zn-O Thin Films Treated with Various Process Conditions,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.176

06/18/2014 34.00 Anders Olsson, Abuduwayiti Aierken, Jani Oksanen, Harri Lipsanen, Jukka Tulkki. Leakage currents of large area InP/InGaAs heterostructures,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.108

06/18/2014 35.00 Yoshitaka Nakano, Yoshihiro Irokawa, Masatomo Sumiya, Yasunobu Sumida, Shuichi Yagi, Hiroji Kawai. Carbon-Related Deep-Level Defects and Turn-On Recovery Characteristics in AlGaN/GaN Hetero-Structures,
MRS Proceedings, (02 2014): 0. doi: 10.1557/opl.2014.102

06/18/2014 33.00 Tianyu Ye, Ramesh Mani, Werner Wegscheider. Microwave reflection study of ultra-high mobility GaAs/AlGaAs 2D-electron system at large filling factors,
MRS Proceedings, (01 2014): 0. doi: 10.1557/opl.2014.107

TOTAL: **42**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 339.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper	
05/13/2014	1.00	Dr. Tim Veal, Steven Durbin, Marius Grundsmann, Anderson Janotti, L. Douglas Bell, Masashi Yamaguchi. 2013 MRS Fall Meeting Proceedings for Symposia R, T, UU, 2013 Materials Research Society Fall Meeting. 03-DEC-13, . : ,

TOTAL: **1**

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

NONE

Graduate Students

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Post Doctorates

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Faculty Supported

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachment

Technology Transfer

Final Report to the Army Research Office
Symposium R: Oxide Semiconductors Block Grant Funding
2013 Fall Meeting of the Materials Research Society (MRS) Boston, MA USA

Grant Number: W911NF-13-1-0488
Amount Awarded: $2910. **Award Period:** 11/20/2012 to 5/19/2013

Prepared by: Tim D. Veal
Stephenson Institute for Renewable Energy and Department of Physics
University of Liverpool
Chadwick Building, Peach Street
Liverpool L69 7ZF
+44-151-794-3872
T.Veal@liverpool.ac.uk

On behalf of all Symposium R Organizers:

Steven Durbin, Western Michigan University (USA) – Lead Organizer
Tim Veal, University of Liverpool (UK) – Finances Contact
Marius Grundmann, University of Leipzig (Germany)
Anderson Janotti, University of California, Santa Barbara (USA)

1. Background

This symposium was in a series of Fall MRS Meeting symposia, the first of which was held in 2005 with a primary focus on ZnO. Each year since 2011, a broad range of semiconducting oxides have been included. As an addition compared with previous years, this year's symposium included a small number of contributions about semiconductor aspects of complex oxides.

2. Symposium Goals

The organizers proposed the symposium to bring together researchers from around the world to discuss the current understanding of fundamental optical and electronic properties of the broad class of materials known as oxide semiconductors, as well as progress in device fabrication and characterization. In looking beyond ZnO for this symposium, we seek to broaden the scope of contributed and invited papers to include emerging materials which may prove to have more immediate device applications. In addition, it is likely that a deeper understanding of experimental observations of electrical and optical phenomena, interfacial and contact behavior, and device characteristics can be more rapidly achieved by considering several of these materials in parallel.

3. Symposium Attendance

In total, 15 separate sessions were held, spanning four full days of the Fall Meeting. These included 2 evening poster sessions. A total of 15 invited talks, 67 contributed talks and 117 posters were presented. Sessions were very well attended, in particular the high quality invited talks. As in previous years, the Q&A sessions led to many good discussions.

4. Symposium Highlights

We are happy to report that a very diverse set of talks was presented in the symposium, covering a wide range of research at the forefront of oxide semiconductors. In particular, we highlight that the excellent selection of experimentalists was complemented by a diverse group of theoreticians and we believe that this turned out to be a successful approach that was highly beneficial for the goals of Symposium R. In particular, leading theoretical (e.g. Hautier, Lany, Limpijumnong, Lany, Scanlon, Walsh, and Wei) as well as experimental (such as Bierwagen, Glaser, Look, Meyer, and Tuomisto) experts came together to discuss controversial topics in order to push the knowledge in the field. Our experiment of introducing an element of the symposium on complex oxides was successful with very well attended talks from Phil King, Suzanne Stemmer and Jean-Marc Triscone**.**

One of the highlights of the symposium was a study of the band alignment between rutile and anatase TiO_2 [D. O. Scanlon, *et al.*, Nature Materials **12**, 798 (2013)]. The photolysis of water on the surface of TiO_2 was first demonstrated in 1972, but the origin of the superior performance of mixed polymorph samples has remained elusive. Here state-of-the-art computational methods and photoemission found that the band lineup of anatase and rutile is a type-II staggered alignment, in contradiction to the long assumed type-I alignment. This decreases the effective band gap at the interface to about 2.8 eV, increasing its visible light activity. These results help to explain the robust separation of photo-excited charge carriers between the two phases, and it is expected that these findings may help the future development of improved photocatalysts.

As in 2012, from a device perspective, amorphous zinc oxide based semiconductors such as indium gallium zinc oxide (IGZO) and zinc tin oxide featured strongly this year. IGZO in particular, only discovered in 2004, is already being adopted by the semiconductor industry for touch screen display applications, such as smart phones. A number of papers were presented on the performance optimization of transparent amorphous oxide transistors targeted at next generation optical display applications, e.g. ultra-fast wide area displays and next generation 3-D displays. Important issues discussed were the low temperature fabrication of transparent devices on flexible substrates and their switching stability under gate bias and illumination stress.

The trend from 2012 of a greater number of contributions concerned with *p*-type or bipolar oxide semiconductors continued strongly this year, with strong contributions concerning copper oxides and tin monoxide as well as one particularly interesting computational study in which high throughput methods had been used to identify candidate low hole effective mass *p*-type oxide semiconductors [G. Hautier *et al.*, Nature Communications **4**, 2292 (2013)]. Including the additional considerations of dopability and earth abundance, several materials were identified as warranting further investigation: B_6O, $K_2Sn_2O_3$, $Na_2Sn_2O_3$ and ZrOS. We will see whether experimental studies of these materials will feature in future oxide semiconductor symposia.

5. Funding Allocation

The following invited speakers received conference fee waivers (totaling $2,645.00):

Martin Allen, University of Canterbury (New Zealand)
Phil King (University of St Andrew, UK)
Sukit Limpijumnong (Suranaree University of Technology, Thailand)
Bruno Meyer (University of Giessen, Germany)
Andreas Ney (University of Linz, Austria)

This was very helpful in ensuring these speakers attended. They were very accessible during the meeting so that conference attendees had opportunities to speak with them in detail. In addition, a travel award of $265 was made to T. Balasubramanian to assist him attending in order to deliver his contributed presentation.

Summary

Total Budget $2910
Fee waivers $2645
Travel award $ 265
Total expenses $2910
Remaining funds $0

6. Future Directions

Based on the success of this symposium, it was decided to continue as many open issues remain and new opportunities exist to further explore in terms of our understanding of fundamental properties, what happens in doped materials, and the development of devices. While the extended reach of this symposium for 2013 to include complex oxides was successful, this extension will not be repeated in 2014 as directed by the 2014 meeting chairs because of the presence of other symposia in the program covering this area. The lead organizer Durbin for the Fall 2013 symposium is stepping aside to organize the ZnO workshop in Niagara in 2014, while Veal will remain and become lead organizer, retaining Anderson Janotti (University of California, Santa Barbara) who brings strong theory/computational expertise and with the addition of Oliver Bierwagen (Paul Drude Institute, Germany) who has expertise in epitaxial growth and characterization and Masataka Higashiwaki (National Institute of Information and Communications Technology, Japan) who brings knowledge of oxide devices and research in Japan.

Report to Army Research Office
MRS 2013 Fall Meeting, Boston, MA, December 1-6, 2013
Symposium T: Compound Semiconductor Materials and Devices

Objectives

Compound semiconductors impact our lives in countless ways, with applications in photovoltaics, wireless and optical telecommunication, high-power electronics, and "green" energy. Recent areas of progress include sensing devices in biological and chemical environments, high-efficiency power devices, and photon-counting detectors. Although these materials offer significant advantages, including bandgap tailorability, high efficiency, high-temperature operation, and radiation tolerance, much work needs to be done to realize their full potential.

Symposium T (Compound Semiconductor Materials and Devices) encompassed topics related to new methods for growth and characterization of compound semiconductor materials, as well as novel device design and implementation using these materials. Both the development of novel devices using conventional materials and the development of new materials themselves were focuses of the symposium. Materials topics covered in the symposium included BN, III-nitrides, ZnO, CIGS, and SiC, as well as hybrid systems combining these materials in their bulk and nanostructured forms. Several sessions focused on quantum structures form a part of the symposium, including work on nanowires and nanocrystals/quantum dots for optical and biological applications. Evolving growth methods such as atomic-layer deposition, self-assembly, and use of nano-engineered templates were covered in this symposium.

Research Highlights

The presentations were divided into several areas:

(1) Nanostructures
(2) Defect Generation and Characterization
(3) III-Nitrides I: Epitaxy and Electronic Devices
(4) III-Nitrides II: Optical Devices
(5) III-V and II-VI: Epitaxy and Devices
(6) IV-IV and Oxide Semiconductors: Epitaxy and Devices

The invited speakers covered important areas of current research and development in compound semiconductors materials and devices. Nanostructure device results were presented by Michelle Povinelli (USC) and Chennupati Jagadish (Australian National University), who showed breakthrough results in nanowire solar cells and lasers. Tsenunobu Kimoto (Kyoto University) presented a comprehensive overview of SiC devices for power applications. III-Nitrides were also strongly emphasized in the Symposium, with Alan Doolittle (Georgia Tech) describing recent advances in high-quality growth, and Uttam Singisetti (University at Buffalo) presenting current device applications. Finally, Neeraj Tripathi (GlobalFoundries) gave an excellent summary of commercial drivers in the compound semiconductor markets.

The Symposium T organizers used the ARO grant for awards to student speakers at our Symposium. The grant provided partial support for a total of 11 students whose talks or posters were judged to be superior. The organizers evaluated the talks and posters based on three criteria: (1) innovation of the work, (2) importance of the work to advances in materials science

and technology, and (3) presentation quality. Among the highlights of the student presentations was a Poster Award winner, Najeb Abdul-Jabbar (Cal Berkeley), for his poster "Structural Vacancy Ordering in the Ga_2SeTe_2 Compound Semiconductor and Its Role on Material Properties." Other excellent student presentations included Roman Vaxenburg (Israel University of Technology, Haifa, Israel) "Suppression of Auger-Stimulated Efficiency Droop in Nitride-Based Light Emitting Diodes" and Elaheh Ahmadi (UCSB) "The Effects of Dislocation, Interface Roughness, and Alloy Scattering on the Mobility of the Two Dimensional Electron Gas in AlGaN/GaN and AlGaN/AlN/GaN."

Contributions to the Discipline

The symposium brought together researchers and engineers working on both fundamental materials research and device-related materials engineering, in order to address current problems and identify next-generation applications. Its goal was to provide a forum for cross-fertilization between research and development of different materials or different classes of devices. The scope of papers demonstrates the cross-fertilization of ideas that will drive the successful adoption of these materials for new applications.

Future Directions

Future symposia will carry on the topic of compound semiconductor research, development, and applications. Although the history of the field spans many decades, new materials and applications are continually spurring new advances in the field. Our organizing group is proposing a new symposium for the Fall 2015 that targets non-traditional applications for compound semiconductors. Semiconductor materials and devices have historically found widespread application in computing and communications. As semiconductor technologies have evolved and matured, end users in many disciplines have also benefited from the advances in miniaturization, capability, and power savings that have been achieved. These areas include energy generation and storage, spacecraft instruments, deep borehole operation, automotive devices, and biomedical devices, to name only a few.

In order to further advance progress in these fields, it is often desirable to target specific applications from the start of development, leveraging from rather than adapting materials and devices developed for more mainstream applications. For example, space, automotive, and borehole applications place severe environmental demands (radiation, temperature, pressure) on optical and electronic devices. Medical microdevices designed to operate inside the body must meet strict requirements of biocompatibility, hermeticity, ultralow power dissipation, and operating temperature. These applications thus place design constraints and requirements on semiconductor devices (and on their packaging) that are often not necessary for commercial applications. The organizers hope that an emphasis on these non-traditional application areas will further hasten the development and dissemination of compound semiconductor microelectronics into under-emphasized areas.

ARO Technical Report
Symposium V, "Enabling Metamaterials: From Science to Innovation"

Symposium V at the 2013 Fall MRS Meeting was an unmitigated success. We attracted the top researchers in metamaterials and related fields as speakers, leading to standing room only crowds for many of our sessions. The objectives of our symposium were to explore, discuss, and showcase advancements in metamaterials related to information processing, and energy-related applications. This choice was quite topical, as sustainability and energy consumption awareness are slowly emerging as 'hard' design criteria in the engineering disciplines.

We received over 50 abstracts for our symposium. Throughout the week, our symposium included talks from 14 invited speakers and 35 contributed talks, as well as a poster session. Much of the work presented was either sponsored or closely related to the mission of ARO. For example, our symposium featured work on new materials such as negative index composites with cloaking properties; new research on Meta-Molecules and 3D metamaterial design for adaptive-materials applications; new computational methods for understanding fundamental mechanisms responsible for revolutionary metamaterial properties; new work on plasmonics-enabled, ultra-fast nano-optical control and ultrasensitive detection; and emerging synthesis and processing techniques, including methods based on directed self-assembly, for scalable production of multifunctional metamaterials.

Highlights included reports on significant breakthroughs in metasurface design and implementation, as well as important advances in fabrication and engineering of novel materials and integrated devices. ARO's support is playing a key role in helping the continued growth and success of metamaterials; among the many excellent presentations, four early-career scientists were singled out for ARO-sponsored awards and support for outstanding oral and poster presentations. We look forward to continuing with this symposium in the future, emphasizing the field's efforts on greatly extending and expanding Moore's law in form of a photonic roadmap, and identifying novel directions for energy conversion. By bringing together scientists and engineers from a variety of disciplines and providing them with the opportunity to highlight the most recent progress, we will continue to engage our (expanding) community in active discussions towards shaping future applications and functional devices.

Keynote speakers

V1.02 Mark Brongersma, Device Applications of Metafilms and Metasurfaces
Monday, 8:30AM—Room 209, Hynes
Metafilms and Metasurfaces have much potential to revolutionize optics and photonics device design. Multifunctionality is expected.

Abstract: Many conventional optoelectronic devices consist of thin, stacked films of metals and semiconductors. In this presentation, I will demonstrate how one can improve the performance of such devices by nano-patterning the constituent layers at length scales well below the wavelength of light. The resulting metafilms and metasurfaces offer opportunities to dramatically modify the optical transmission, absorption, and reflection properties of devices. To illustrate these points, I will show how nanopatterned metals and semiconductor layers can be used to enhance the performance of photoelectrodes for water splitting, photodetectors, and solar cells.

V1.08 Vladimir M. Shalaev, From 3D to 2D Metamaterials
Monday, 11:00AM—Room 209, Hynes

Metamaterials are exciting new materials with properties not found in nature, enabling exotic phenomena like invisibility.

Abstract: Recent progress in the development of optical metamaterials allows unprecedented control over the flow of light at both the nano- and macroscopic scales. Metamaterials (MMs) are rationally designed artificial materials with versatile properties that can be tailored to fit almost any practical need and thus go well beyond what can be obtained with "natural" materials. We review the exciting field of optical metamaterials and discuss the recent progress in developing tunable and active MMs, nanolasers, artificial optical magnetism, semiconductor-based and loss-free negative-index MMs, and a new means for engineering the photonic density of states with MMs. A powerful paradigm of shaping space for light with transformation optics, which can enable a family of new applications ranging from a flat magnifying hyperlens to an invisibility cloak, will be also discussed. Finally, we review a new approach for controlling light by using meta-surfaces. Similar to the surface science that in the past revolutionized the physics and opened up a family of new phenomena and applications unattainable with 3D systems, we envision that metasurfaces can make a difference for the fields of metamaterials and transformation optics as well as for the science of light in general.

V4.01 Sir John Pendry, The Sub Nanoscale Optical Response of Plasmonic Materials
Tuesday, 1:30PM—Room 209, Hynes
Nanoscale plasmonic optics creates extremely strong light matter interactions. This enables for orders of magnitude smaller devices and new scaling trends for opto-electronics.

Abstract: In optics we generally describe a material by its electrical permittivity. Sometimes the permittivity is dispersive and depends strongly on frequency, as is the case for metals, but usually it is assumed to be independent of wave vector. This assumption works well on the scale of the wavelength of light, but current experiments on nanostructured materials challenge this assumption. Theorists are still debating the correct model permittivities observed at the sub nanoscale. I shall discuss the theories, how they can be implemented to calculate optical properties, and how they also have consequences for the Van der Waals interactions and heat transfer between nanoparticles.

Symposium Organizers
Volker Sorger (George Washington University)
Jim Schuck (LBNL)
Luke Sweatlock (Northrop Grumman)
Jennifer Dionne (Stanford University)

Report ARO support for a Symposium UU in MRS Fall 2013

Symposium UU: *Phonon-Interaction-Based Material Design-Theory, Experiments, and Applications*

Reported by Masashi Yamaguchi,
Department of Physics,
Rensselaer Polytechnic Institute, Troy, NY 12180

Objectives: The symposium addressed the issues in the materials designs based on phonon interactions. Phonon interactions play a significant role in determining mechanical, thermal and physical material properties at various structural dimensions. Materials design based on controlling phonon interactions is steadily evolving. In spite of the significant progress has been made in our ability to understand and control phonon dispersion and transport in nanostructures, phonon transport across and along interfaces, the scattering of phonons with crystal defects, and phonon mediated electron cooling, gaps between fundamental understanding and technological needs still remain, particularly in our understanding of phonon-phonon, phonon-interface and phonon-defect interactions. To close these gaps will enable the design of materials that provide novel solutions and enhance our scientific knowledge of applications in areas including nanomechanics, thermoelectrics, nano-photonics, plasmonics, hot carrier photovoltaics, terahertz phononics, thermal rectification.

Presentations: The symposium had 67 oral sessions and 1 poster session and continued for three and a half days. It attracted 62 presentations including 14 invited speakers and 6 posters. Seven oral sessions were held and the titles of the sessions are: Phonon modes and dispersion relation, Phonon thermal transport in nanomaterials I &II, Thermal transport in bulk materials, Phonon devices, phononics and coherent acoustics, and vibrational properties and phonon interactions.

Highlights: 14 invited talks were highlights of the symposium. Dr. Judy Pang of ORNL gave a talk on the Phonon Properties and Thermal Transport of UO_2 by Inelastic neutron scattering. Prof. Cilvia Sotomayor Torres of U. Valencia gave a talk on the experimental study on phonons in Free-standing Silicon Membranes. Low frequency phonon modes in Free-standing membrane, and engineered thermal conductivity were discussed. Prof. David Cahill of U. Illionis gave at talk on extremes of heat conduction in molecular materials. Prof. Gang Chen gave a talk on Ballistic and coherent phonon transport in bulk materials and nanostructures. In Application side, Dr. Paulo Santos of Paul-Drude institute gave a talk on Acoustic exciton multiplexers which uses surface acoustic waves for the manipulation of exactions in semiconductors. Prof. Gren Sun of U. Massachusetts, Boston gave at talk on THz GaN quantum cascade laser using surface Plasmon waveguide.

Contributions to discipline:
Experimental study of phonon dispersion in UO_2 revealed that the role of optical phonons in thermal transport, and particularly that the Density Functional Theory cannot reproduce the phonon dispersion in UO_2. Theory of lattice thermal conductivity computations based on various of methods including phenomenological and ab-initio computations were reported in the symposium, however, the reported experimental results indicate that further refinement of theoretical prediction of thermal conductivity is necessary. non-Fourier thermal transport extremes of heat conduction in molecular materials effect of interfacial adhesive layers on thermal conductivity ballistic and coherent heat conduction in nano materials(nano composites) GaN electronics, sasers excitonic devices, QCL, integrated photonic devices were reported in the symposium. The challenges to be met include accurate reproducible measurements of interface thermal resistance, improved theoretical treatments of phonon boundary scattering, interface scattering, interface resistance anomalous anharmonic scattering, anharmonic scattering in nanocomposites.

Future direction for the symposium topic: Continuing effort for the understanding of the phonon transport and interactions in nanoscale and bulk materials need to be addressed again in future. In addition, novel concepts for phonon devices based on the phonon wave nature are presently emerging. Examples include the quantum control and transport of spins as well as the manipulation of quantum dots and of polariton condensates using phonons. At the same time, a number of novel techniques for the generation, detection, and manipulation of coherent phonons has been developed. Detection, manipulation and modeling of the coherent nature of the fundamental interactions between phonons and electrons, spins, excitons, and other elementary excitations is another thrust in this symposium. Closing the gap between the fundamental understanding and demands on engineered phonon properties in materials will enable the design of structures that provide novel solutions and enhance our scientific knowledge of applications in areas including nano-photonics, plasmonics, photovoltaics, terahertz photonics, and nanomechanics, etc.